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BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

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CONTROL OF WESTERN PINE BEETLE

ON THE

SAN JOAQUIN PROJECT

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Northfork, Calif.
December 20, 1924.

Entomologist.

GOVERNMENT PRINTING OFFICE

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Summary - San Joaquin Project

Conditions and Purposes of Project

An area of approximately 130,000 acres with 900 million board feet of yellow pine was selected by the Bureau of Entomology and Forest Service as the testing ground for methods of maintenance control of the western pine beetle.

Annual losses when project was initiated did not exceed one-half of one percent of the stand, averaging from one tenth to four tenths of one percent or from one to three million board feet. Under this degree of loss the infestation is termed normal or endemic.

The object of this experiment was to carry on control work against endemic infestations for a period of five years to determine:

1. Possibilities of improved control methods.
2. Whether endemic losses can be reduced.
3. Whether increase starting from endemic conditions can be checked or prevented.
4. Whether amount of timber saved by such control methods can be sufficient to warrant cost of work.

Outstanding Results of Project.

1. Experimental Methods.

    1. Solar heat as a method of treating infected bark can be used to advantage in supplementing burning in June, July and August. Burning is the most satisfactory method to use, however, when it can be employed without undue fire hazard.

2. Trap Trees.

Trees felled and shaded during summer season will attract beetles to the extent of infesting the greater part of the bark surface. However they will not successfully localize the infestation or materially reduce attacks in standing trees unless employed on a wholesale scale which would be impracticable in control work.

3. Summer Work.

Work carried on during the summer season by small crews is feasible and a low percent of the infestation can be treated. From an administrative standpoint, however, this work is less efficient than winter and spring work carried on by large well organized crews.

Summer work can be of little benefit, however, except for maintenance control.

II. Maintenance work.

1. Treating a low percent of infestation over large areas. By working with small crews of two to four men, moving over the area and treating the more accessible trees, from 16% to 40% of the seasonal infestation was treated during 1920 and 1921. A decline followed this class of work in 1920 but it was no more effective than the decline on areas where no control work was done. In 1921 when an increase occured no appreciable preventing or checking of losses could be noted as a result of these control measures.

2. Treating 40% to 50% of infestation on small units.

By working areas of less than 5,000 acres more intensively, it was possible to treat 40% to 50% of the seasonal infestation during the season of 1922 and a decrease in 1923. These fluctuations, however, correspond closely to those in adjoining areas where no control work was done and the benefits are no more apparent than where the natural factors were allowed to run their course.

3. Extermination.

By working a small area of 3,600 acres with both spring and summer work, using the most intensive methods feasible it was possible to treat about 90% of the seasonal infestation . This work seemed to be of some effect in checking an increasing infestation. Compared with adjoining areas in 1922 a potential increase of 67% was prevented and a 19% reduction secured. However, the cost of this work was considerably greater than the value of the timber that was saved, assuming that a 60% increase occured on the control area if no work had been done.

In 1923 a decline of more than 35% was secured but this decline was less than that on adjoining areas wgere no control was carried out.

During the season of 1924 the unit was practically cleared of all overwintering infestation but by the close of the season was again reinfested to the same extent as adjoining units where no control work was carried out. The extreme drought conditions of this season may have aggravated this result.

A further cruise in 1925 is necessary to determine the extent of the 1924 infestation. However, results of project to date tend to prove that, against endemic infestations where losses are less than one half of one percent of the stand annually, the cost of control work is not warranted by the benefits secured.

A comparison of the results on this project with projects covering relatively large areas such as the Antelope and the Southern Oregon, Northern California where control work was directed against losses proportionately higher, running around one percent of the stand annually, show that a much more effective reduction was secured on the latter areas. The results of the San Joaquin project are apparently not applicable where the infestation is epidemic to the extent that losses are higher than half of one percent of the stand. The exact point where an infestation may be considered sufficiently aggressive to make control work worth while has not been determined as a result of these experiments.

Future plans.

Further experimental work to determine the feasibility of maintenance control is apparently unnecessary. Investigations should be carried on, however, to determine;

1. Natural factors governing increase and decrease of infestations.
2. Possibility of reducing endemic losses through silvicultural practices and methods of management in future stands.

CONTROL OF WESTERN PINE BEETLE ON THE SAN JOAQUIN PROJECT.

Historical

The first measures to control losses entailed by the western pine beetle in yellow pine were started in California in 1911. Up to 1920 approximately $90,000 had been spent in treating twenty million feet of infested timber mainly in District 5. Some fairly successful reductions of losses were secured but, at the same time, a number of unsatisfactory features connected with the application of direct control methods were uncovered as a result of these pioneer projects.

Control measures were usually directed against situations where decided increases in the volumne of beetle killed timber had recently occured. Such looses were usually more than 50 trees per section but did not exceed 1 6r 2 percent of the stand annually. It can be shown that reduction of losses followed control work in the majority of projects, especially where losses were high. However, such reductions were not uniformly successful and various inconsistencies in results indicated that factors other than the artificial control had much to do with the resultant progress of the infestation.

Representatives of the Forest Service and the Bureau of Entomology in a conference held at Ashland, Ore.,n in January 1917, were agrred as to the proposition that these intangible factors should be studied before intensive control measures were undertaken, and that control of the western pine beetle should be taken up as an experimental measure. This led to the so-called "Ashland Conference Plan" the object of which was to test out various factors of the problem by experimental methods.

Objectives of Maintenance Control

One of the major problems considered in the plans for this experimental work was the development of some system of protection whereby the so-called epidemic situations could be fore-stalled. It was conceded that, if control measures could be successfully applied just at the time that the beetles were starting to increase their numbers, it would require less work to stop them and a considerably greater saving of timber would result. The objective in this method of attack would be to hold the infestation to the endemic stage considered to be the lowest point to which losses can be reduced by artificial control or natural factors. Dr. A. D. Hopkins originally suggested this idea in bulletin 83 under the discussion on Page 32, "How to maintain Control". The term of maintenance control has therefore been used to designate this system.

To make a thorough test of maintenance control was the primary object of the San Joaquin project. It was realized at the time that natural factors of control might be much more effective than the attempted artificial methods. However, very little was known about the underlying causes of the increase or decrease of pine beetle infestations as funds were not available to adquately develop this line of investigations. It was considered, however, that by directly applying maintenance control for a considerable period and carefully checking the results, its usefulness would eventually be proven or disproven as other factors would finally be compensated.

Maintenance control could only be tested under this assumption by carrying out a plan of protection on a selected area for a period of years. The plan recommended by the Ashland Conference in 1919 involved:

1. The selection of a representative well defined area of yellow pine type.

2. A general clean-up of the entire area to remove epidemic conditions.

3. Continuation of maintenance control work for a period of five years on all or part of the area.

4. Study of uncontrolled infestations on suitable check area.

It was considered that control work throughout the season from April to October would be the best plan of maintenance work as increases starting during the early part of the season could be checked before a second generation of beetles developed. At the time the use of solar heat as a means of destroying western pine beetle broods in infected bark had just been developed. This method made it possible to continue control work throughout the summer without risk of fires from burning infested bark, the only method that had been employed up to that time.

The use of selected trap trees was also considered as a phase of the summer work. The trap tree was designed to keep the beetles from attacking more valuable standing trees and to localize the infestation at accessible points.

SAN JOAQUIN AREA

The belt of pine timber lying on the northern drainage of the San Joaquin river of the Sierra National Forest was recommended as the testing ground for this work. This area includes about 130,000 acres of yellow pine, sugar pine type with two billion feet of stumpage. It is protected by complete type barriers on three sides. At least 75% of the area is under the administration of the Sierra National Forest, the remainder consisting of one large block owned by a private lumber company. During the period from 1913 to 1919 insect losses in yellow pine and sugar pine had attracted considerable attention and approximately $24,000.00 was spent by Federal and private agencies in treating seven million feet of infested yellow pine and sugar pine. The annual losses during this period are estimated to have averaged 4,800,00 bd. ft. annually.

The Stevenson Creek area, just south of the San Joaquin river, was selected as a check. This check area, which was established by Mr. Ralph Hopping in 1914, consisted of 2,500 acres with a stand of 16 million board feet of pine.

Cooperation and Finances on Project.

The initial working plan of the project provided that the actual cost of the control work, disbursement of funds and administration of field work would be carried out by the Forest Service through the Sierra National Forest, while the technical supervision would be provided for by the Bureau of Entomology. In order to administer this work, the Bureau of Entomology established a field station at Northfork and contributed the services of one Entomological Ranger throughout the progress of the experiment.

Progress Reports.

The following reports have been submitted from time to time covering in detail the progress of the work from the time it was initiated until the close of the 1924 field season.

Working Plan - San Joaquin Insect Control Project						- June 1, 1920
First Annual Report,	"	"	"	"		- May 1921
Revised Working Plan	"	"	"	"		- April 26, 1922.
1st Progress Report	"	"	"	"		- " 10, 1923.
2d " "	"	"	"	"		- February 1924.
3d " "	"	"	"	"		- December 1924.

Phases of Experimental Work

The progress of this experiment has covered two distinct phases during the five years that it has been in effect.

The first phase consisted of a direct attempt to apply the original conception of maintenance control to the entire area to be protected, with the study of one check area as a comparison. This involved a trial of summer work together with the feeling out of methods and their effectiveness. Two relatively new features, the use of trap trees and solar heat treatment of infested bark, were included in these tests. This first phase of the project covered the two seasons of 1920 and 1921.

The second phase of the project consisted of a much more intensive application of the more promising lines of development uncovered during the first twonseasons. This work was entirely experimental in character, designed to test the effectiveness of maintenance as applied with different degrees of intensity on separate units. In order to handle this work adequately with the funds available, the area covered by control work was cut down to 20,000 acres, but the balance of the project covered by a 100% annual cruise. The second phase of the project which is now nearing completion was carried on during the seasons of 1922, 1923 and 1924.

History of Work

The following discussion considers only losses in yellow pine and control of the western pine beetle in this host, as the primary purpose of the project was to determine the feasibility of maintenance control of this species. The yellow pine losses are all primarily due to the western pine beetle with some infestation of associated insects such as Ips and flatheads. The mountain pine beetle in sugar pine and the flathead (Melanophila sp.) in Jeffrey pine figure to quite an extent in the losses and more or less control was carried on against these insects. This phase of the project has been considered in all previous reports. However, the infestation in these two hosts is quite distinct from that in yellow pine.

Season of 1920

Control work was initiated in March 1920 upon the infestation overwintering from the fall of 1919.

The losses in yellow pine for the preceding year amounted to .24 of 1% of the stand.

Spring Work. A preliminary survey was made to determine the areas where control work would be necessary. The plan of control for the spring work was to make a general clean-up of the entire area by working those sections of it where the losses were above 25 trees to the section. Work was carried on over about 70,000 acres of the project area, it being considered that for the remainder the infestation was too low for spring work to be carried on to advantage as infested trees were too scarce to profitably employ large crews. During this period from March 8 to April 5, 300 trees with a total volumne of 545,490 board feet or about 73% of the total overwintering infestation on the area was treated.

Summer Work. After this initial clean-up of the area summer work was started on June 15 and closed down about October 1.

One crew of two men was assigned to the Northfork District. This crew traveled with a light Ford truck and worked the area assigned from roads. Another crew of two men was assigned to the Chiquito District, traveling by pack outfit. In both districts the plan was to keep the crews moving through the area, treating accessible standing infested trees and windfalls. The same route was covered at an interval of about 5 or 6 weeks so that altogether three trips would be made over the same sections of the area during the course of the season. Occasional trap trees were felled at accessible points and later treated if infested on subsequent trips.

During the summer work a total of 91 standing trees, 74 windfalls, and 151 trap trees with a total volumne of 486,000 board feet were treated or about 37% of the infestation developing during the season. About 25% of the standing infested trees were treated. The annual losses for the entire season amounted to .14 of 1 percent of the stand.

Season of 1921

Only summer maintenance work was carried on this season as it was evident that the volumne of overwintering infestation was much less than that of the preceding year and the organization of large crews to handle spring work did not seem practicable. Work was carried on in about the same manner as 1920 except that a one man crew instead of a two man crew was assigned to the Chiquito District during the period from May 15 to August 15. The work in the Northfork District was carried out as in 1920 by two men. Altogether, 117 standing trees with a volumne of 161,960 board feet and 230 trap trees and windfalls with a volumne of 188,390 board feet were treated during the course of the summer work. This represented approximately 32% of the total infestation developing on the area in the summer broods.

Toward the end of the summer it became apparant that the infestation was tending to increase generally over the entire area. The total lossfor the season amounted to .2 of 1 percent of the stand. While the control work had been carefully done, it was evident that was not enough to stop this increase.

Season of 1922.

In view of these results, three questions were prominent in considering plans for further work on the project. Would a more intensive cruising and thorough working of the area be necessary to check this increase if the tendency continued in 1922? If more intensive work was the answer, to what extent must it be carried to be effective? Would a more adequate use of trap trees be of any advantage in checking this increase?

It was evident that the answers to these questions could only be determined experimentally. To increase the intensity of the work for experimental purposes would only increase the cost. As funds for the project were limited, it was necessary to decrease the area under control work.

Under the plan finally agreed upon, actual control work was limited to approximately 24,000 acres in the Chiquito District and the entire balance of the project was cruised on a 100% basis.

The control area was divided into six topographic units averaging from 3,000 to 6,000 acres each. One check was selected and adjacent to the control units where conditions were entirely similar. Two check units were also selected at some distance from the control units where there was little likelihood of the infestation being influenced by the work on the control units.

These units are described as follows:

Unit	Acreage	Volumne Yellow Pine	Character of Control Work
26a	54,440	43,500 M.B.M.	Spring and summer work with trap trees. treating the more accessible trees so as to get 50% or more of the infestation.
26b Forked Mdw.	3,200	36,894 " " "	Extermination by continued spring and summer work. 100% of the infestation to be treated if possible.
26c West Chiquito.	5,760	69,120 " " "	Spring and summer work without trap trees, treating the more accessible trees so as to get 50% or more of the infestation.
26d Arnold Mdw.	5,120	61,440 " " "	Occasional spring and summer work in accessible parts of the area.
28 Dalton	3,200	19,200 " " "	Spring work only without trap trees.
27 Jackass	6.400	49,920 " " "	No control work. Check adjacent to control areas.
24b Rock Creek	7.680	92,160 " " "	No control work. Check area at some distance from control work.
30 Crane Valley	7,680	61,440 " " "	Spring and summer control work in 1920 and 1921. Check area distant from control work.

An accounting system of the time spent on each unit was initiated as a means of determining the varying costs of the different systems of control work. In addition an experiment was carried out to more efficiently test the effectiveness of trap trees in localizing infestation and drawing attacks from standing trees.

All of the control units, with the exception of 26d were covered with spring control work in 1922, a crew of 12 men being employed for the period from April 1st to May 15. The work was then taken up by a crew of three men and continued until October 15th.

During the season of 1922 the infestation continued to increase in the majority of units. The only control unit which registered a decline from 1922 was 26b where the intensive extermination work was under way. The total loss for this season amounted to .29 of 1 percent of the stand.

Season of 1923.

Control work was limited to units 26a, 26b, 26c and 26d. The spring work on 28 was dropped due to difficulties of establishing a separate camp on this unit. Spring work was started on March 25th and continued until May 10th. A twelve man crew was employed and a fairly thorough working of the overwintered infestation was secured.

Summer work was carried on by a crew of three men from May 15th to October 10th. During the season of 1922 the experimental work with trap trees demonstrated that they were of little value in localizing attacks of the beetles or in checking the increase of that season. For these reasons the use of trap trees was discontinued entirely in 1923. The summer work was largely concentrated on extermination work in Unit 26b where 35% of the total time on the area was expended.

The progress of the infestation during this season was one of general decline, the total loss dropping to .19 of 1 percent of the stand. This decrease was equally evident on both control and check units.

Season of 1924.

Spring work was started April 5, with a six man crew and continued until April 20th. The overwintering infestation was the lightest on record with the exception of 1922. Spring control was extended over Units 26a, 26b and 26c.

Work on Unit 26b. On the extermination Unit 26b an special effort was made to clean up all the overwintering infestation, the unit being worked three times during the fall, winter and spring in the effort to get all of the overwintering trees. As a result 89% of this infestation was treated. Two men were employed on summer work from June 1st to August 31st. It was considered that more information of direct values would be received by following up closely results on the extermination unit than by spreading the work over the other area.

Starting with this comparatively clean area, a study was made of the drift of new infestation from the outside into the unit. A special effort was made to treat all newly infected trees as soon as they could be located. Before the close of the season, however, infested trees were appearing much faster than the two man treating crew could handle the control work.

The precipitation for the winter and spring of 1924 was but 50% of normal and the lowest recorded in the history of the ewather records of this region. The infestation, however, showed very little tendency to increase until after August 1st. Trees were being attacked during June and July by very light broods of beetles. Before the close of September, however, heavy attacks and heavy broods in the infested trees were abundant everywhere. The extent of the increase for this season cannot be determined until 1924 but it promises to be the heaviest of any year in the history of the project.

Progress of Infestation on Check Areas.

1. Stevenson Creek . This area was first established as a check area by Ralph Hopping in 1915, as a following-up study of control operating carried on in the spring of 1914. The area consists of a topographic unit of 2,500 acres located in T. 9 S., R. 24. E., Mount Diablo Meridian. It is about 10 miles southeast of the San Joaquin units and separated from them by the distinct type break of the San Joaquin Canyon. The stand is estimated at twelve million feet of yellow pine. Records of the loss on this area are now available for a period of ten years. These were kept by Mr. Hopping until 1918 and have been continued by the Bureau of Entomology from then on.

In the spring of 1914 the volumne of overwintering infestation amounted to 264,000 feet. 76% of this volumne was treated. The infestation declined in 1915 and 1916 when it amounted to only 85,000 board feet. In 1917 the loss increased to 218,000 board feet. A decline set in in 1918 which continued until 1920 when the loss was only 27,000 board feet. In 1921 there was an increase to 92,000, in 1922 a decline to 59,000, and an increase to 85,000 in 1923.

The outstanding features of this check area are:

1. The decline in 1920 and the rise in 1921 conform to the decline and rise during the same season onevery unit of the project.

2. The decline from 1917 to 1920 when no control work was done is considerably more marked than the decline from 1914 to 1916 after 76% of the infestation had been treated.

3. The decline in 1922 and rise in 1923 differed from the majority of the units but only to a slight degree. One explanation for the 1922 decline is the Dawn fire which occured on the northern boundary of the unit during the summer of 1921. This fire resulted in many scorched trees which attracted broods of beetles during the season of 1922. It is probable that this burn attracted some of the beetles from the Stevenson Creek Unit

4. This check area indicates that the natural factors of control affected the infestation on the check area to about the same extent as they did on the units of the San Joaquin area, although no control work was carried on in the check area during the period from 1919 to 1923.

2. Jackass Creek. This area bordered directly on 26b where intensive control work was under way and also on unit 26d. The area was not selected as a check until 1922 and the losses recorded for 1919, 1920 and 1921 were secured by "back marking", that is, red and black-topped trees were assigned to the year loss according to the judgement of the estimator. This may account for the relatively low loss in 1919.

Conditions in this unit are practically identical with those in Unit 26b and other units of the Chiquito Basin. No trees were treated in this unit except an occasional tree along the boundary between units 26b. It is quite possible, however, that control in adjoining units may have had some influence on the course of the infestation in this check unit. The out-standing features of this unit is the pronounced increase during 1921 and 1922 and the decline of more than 50% in 1923.

3. Rock Creek. This area is separated by a fairly distinct topographic barrier from the units in the Chiquito Basin. A small amount of infestation was treated in the spring of 1920, but no trees were treated thereafter. The unit has fairly good site conditions and has never been subject to very heavy losses. The percent of the stand killed annually is less than in the Chiquito Basin.

This unit showed a rather pronounced increase in 1921 and 1922 and a decline in 1923 quite similar to that in the Jackass Unit.

Results of Experimental Features of Project

1. Solar heat as a control method.

This method has been continued in actual use during the life of the project and a careful study made of results.

The method is effective in killing broods if the bark is fully exposed to the sun for a few hours during the day in the months of June, July and August.

It can be used to advantage to supplement burning of bark where fire danger is great.

The method requires considerable care to be successfully applied and as a rule is more tedious and expensive than burning. Logs must usually be rolled in order to get the bark from the under side. Even when great pains are taken the method does not insure as thorough a job as burning. During the summer, burning was used instead of solar heat whenever practicable as the men preferred going to considerable work in making the fire lines safe rather than peel all of a tight barked tree.

2. Use of Trap Trees

543 selected trap trees with a volumne of 361,140 board feet were felled during the five seasons of control work. The distribution varied from two to the mile to 24 to the mile and in one experiment were distributed in the form of a circle around a clean area. Results demonstrated that:

1. That although the majority of traps successfully attracted attacks of beetles standing trees were often equally as attractive to the beetles and the killing of such trees could not be prevented by the use of traps.

2. That trap trees distributed in relatively small quantity over an area were not effective in localizing the infestation at accessible points and would not prevent an increase of the infestation in the surrounding timber stand.

3. While the use of trap material on a large scale comparable to that furnished by a logging operation may possibly have some effect in preventing a general increase of infestation in the surrounding area, the use of trap material on so large a scale is not practocable in maintenance control work.

3. Effectiveness of Treating a Low Percent of the Infestation

During the first two seasons of 1920 and 1921 when control work was spread over the greater part of the project area from 16 to 29 % of the seasonal losses were treated.

Results indicated that the treatment of so low a percent of the infestation was of little avail when natural conditions favored an increase of the beetles. In 1921 the increase on the control areas was fully as much as on the check areas.

4. Effectiveness of Treating from 40% to 60% of the Infestation.

In 1922, the system of control initiated on the Logan Unit(26a) and west Chiquito(26c) was designed to treat about 50% of the seasonal infestation. This was continued in 1923. The units were covered two or three times each season and the more accessible trees treated. The percent of infestation treated in this way varied from 42% to 48.80%.

The treatment of the 1922 infestation was followed on both units by a decline in 1923. However, this decline was no more pronounced on the control areas than on the check areas and in fact was considerably less. The effects of the 1923 work which was not followed by an increase in 1924 will not be apparent until the final returns from the 1924 cruising are available.

On Unit 26a (Logan) 61% of the 1921 infestation was treated but this was followed by an increase in 1922.

5. Extermination or Attempted Treatment of 100% of the Infestation

This intensive method of protection was started on Unit 26b in 1922. During the spring and summer periods the unit was cruised at intervals of not more than three weeks and infested trees were treated as fast as they could be located. Under this system it was possible to treat from 80 to 90% of the volumne of infested timber during the seasons of 1922 and 1923. This work was applied as intensively as it was possible to do with the resources available and it is doubtful if a higher percent could have been secured even though a larger crew had been concentrated on the area. This failure to secure a hogher percent of the infestation was due mainly to failure of the foliage of many trees to fade before the new broods of beetles emerged.

This system of control cost from .32 to.45 cents per acre as against .04 cents to .18 cents for the work on units 26a and 26c.

In 1922 about 78 percent of the summer infestations was treated. The overwintering infestation of that season was relatively light and the total loss for the season represented a 19% decline from 1921. As all other control units and check areas regristered an increase for this season it is believed that the persistent control work had some effect.

The general average increase in yellow pine for the Chiquito district amounted to 26%. On the Jackass Unit immediately adjoining the extermination area the increase was 67%. As the yellow pine loss for these units was from 70 to 75 % of the total loss including sugar pine and jeffrey pine, the cost of treating the yellow pine only can be placed at 75% of the total cost of the control work for the unit during the season of 1922. As this cost amounted to $1173. 97 the yellow pine control work cost approximately $880.47. On this basis the values of the work stand as follows:

1921 loss	150,810 mbm
1922 loss	120,850 "
1922 loss if an increase of 28% had occured.	193,030 "
Probable saving of stumpage. .	72,180 "
Value at $3.00 per M	$216.54

Loss on control work. $683.96
Stumpage value necessary in order
for work to pay for itself. 12.20 per mbm

Assuming that the increase would have amounted to 67%, the same as that on the Jackass Unit we have the following comparison.

1922 loss if an increase of 67% has
occured. . . . . 251,850 mbm
Probable saving of stumpage. . . 131,000 "
Value at $3.00 per M. $393.00
Loss on control work. 487.50
Stumpage value necessary in order
for work to pay for itself. $6.70 per mbm.

In 1923 the percent of summer infestation treated was not quite as high as in 1922 but the unit registered a still further decline of about 50 percent. However, the decline on both the Jackass and Rock Creek check units was greater than this as well as on the Logan control unit. The decline was considerably less in West Chiquito.

In 1924 a special effort was made to treat all of the overwintering infestation in the spring work on Unit 26b so as to start the season with a clean area. Development of the new infestation within the unit was followed closely with the idea of keeping the unit clean if possible. By the end of the season this unit was reinfested to the same extent as the surrounding control units and check areas.

The full extent of the 1924 increase cannot be determined until 1925. It is apparently complicated by the extreme drought which prevailed during the spring and summer.

One feature of the 1924 work was a study of the distance of flight of beetles in coming into the clean area. Practically all infested trees that developed in the unit during the season could be accounted for as coming from infested trees not over one mile distant.

Results on this unit to date have demonstrated the impracticability of exterminating or even materially reducing losses from an endemic infestation on a small unit exposed to infestation coming in from outside areas. Even though the cost of intensive work can be held down to 40 cents or less per acre the volumne of timber saved, as compared with areas where no control work was done, does not warrant this expense.

Intensive work if applied to a completely isolated area where no beetles could come in from rhe outside to reinfest clean territory might, however, result in more effective savings.

6. Natural Factors Influencing Progress of Infestation

No provision for studies of this nature was included in the initial plans for the project except to incidentally gather any available information

on this problem. During the last year or two some headway has been made along this line. A study of growth of infested trees as indicated by annual rings when compared with non-infested trees on the same sites have been started and to date about 1,000 cores with data have been collected. So far as they have been studied these indicate that beetles consistently select slow growing trees for attack under endemic infestations.

After the cleanup of the Forked Meadow Unit in the spring of 1924 many infested trees contained only flatheads and a very light scattering attack of western pine beetles. The drought conditions of 1924 undoubtedly had much to do with lowering resistance and vitality of trees and thereby building up the increase of this year.

A detailed study of the relation of site to the amount of infestation and percent of stand killed was started during the summer of 1924 but as yet insufficient work has been done to warrant even preliminary conclusion.

Plans for Further Work

If the results of this project are accepted it is evident that control of endemic losses averaging less than 1/2 of 1 percent of the stand is impracticable with present methods. While some loss of timber is undoubtedly prevented it is impossible on small units to effectively check an increase once it gets under-way. It has also been demonstrated that when natural factors favor a decline the resultant reduction is just as effective on units where no control work has been done as on units where a relatively high percent of the infestation has been treated. The results which will be available in 1925 should definitely settle the feasibility of this form of protection under the conditions of the Southern Sierra Region and further experimentation seems unnecessary.

Results from control projects such as the Antelope and Southern Oregon-Northern California indicate that control work against aggressive epidemic infestations with losses running around 1 percent of the stand annually results in an appreciable reduction of losses and that this work has actually paid for itself in the volumne of timber saved in one or two seasons.

Factors as yet undetermined are the following:

1. The point at which an infestation may be considered sufficiently aggressive to render control work worth while.

2. Natural factors governing increase and decrease of infestations. This involves such factors as parasites and predators, climatic influences, composition and vigor of stand, etc. The direct application of this field of study will be in the forecasting of epidemics.

3. Possibility of reducing endemic losses through silvicultural practices and methods of management.

The object of such studies will be to prevent conditions favorable to the beetles on timber sales, other areas or where new crops of timber are being grown. This phase of investigations will involve studies of susceptibility of certain sites and stands to beetle losses, relation of losses to increment of stand over long periods, and the possibility of eliminating from future stands trees that are especially susceptible to beetle attacks.

The following plans are proposed for continued study on the San Joaquin project area.

1. Preparation of a careful type and site map.
   A map of two or three of the more representative units will furnish sufficient data for this study. This survey will be carried out by a field party during the spring of 1925. This map will serve as a basis for relocation of units and computation of losses.

2. Determination of beetle losses to increment over ten year periods. This will be worked out from selected plots distributed over the entire project area and if possible for its entirety for one selected unit where intensive studies will be located.

3. Stem analysis of beetle killed trees to determine the relationship between rate of growth and mortality, age of susceptibility of dominant trees, and optimum period of rotation from the beetle standpoint. The basis for this will be the records secured from trees which have been cut in control work, cores from trees marked in cruising the entire area and trees cut in intensive studies of entire project area.

4. Selection of an area similar to Unit 26b where intensive studies, involving the cutting of a high percent of infected trees will be carried on for the purpose of:

   a. Analysis of the quantity of infested trees as a basis of estimating the actual increases or decreases of beetle population from year to year.

   b. Numbering of green trees preferably on poor sites to determine if there is any pecularity, such as crown condition, general appearance, time of budding, etc., such as might be used as a criterion of susceptibility of attack.

   c. Studies of influence of parasites and predators on progress of infestation.

5. Study of annual losses as correlated with precipitation.

6. Selection of plots within areas where timber sales are in progress and applying experimental marking with the object of eliminating trees susceptibile to beetle attack from stand reserved for second cutting.

7. Continuation of site study initiated during 1924 season.

Cooperation and Financing of Project.

As the problem proposed for study essentially concern the forester and the progress of investigations will involve consideration of factors which lie within the province of forestry rather than entomology, full cooperation between the Forest Service and the Bureau of Entomology, both in the planning and conduction of this work, is necessary to its success.

The following plan of cooperation is proposed:

1. That the Bureau of Entomology, through its field station at Palo Alto and substation at Northfork, provide the personnel and salaries for the project.

2. That the Forest Service provide field expenses for Bureau men engaged on this work.

Estimates - Fiscal Year 1925.

The present balance of approximately $500.00 is considered sufficient to carry field expense plans for this work during the spring period of April May and June, 1925.

Fiscal Year, 1926.

The field expense involved in carrying on thos work through the fiscal year 1926 is estimated at$1000.00. This will cover expenses of Bureau of Entomology men and hire of labor in cutting infested trees.

TABLE I.

Comparative Costs and Percent of Infestations Treated on Individual Units.

Unit		26A	26B	26C	26D	28
Season 1922	Total Cost	$232.40	$1173. 97	$263.90		$435.49
	Cost per acre	.062	.353	.049		.137
	Cost per MBM	8.22	5.56	4.53		6.88
	% Treated	43.80%	89.92%	42.65%		62.70%
1923	Total Cost	756.82	1177.59	994.71	519.48	
	Cost per Acre	.145	.367	.185	.099	
	Cost per MBM	5.95	8.35	5.21	5.43	
	% treated	45.90%	78.72%	39.45%	42.72%	
1924	Total Cost	268.50	1075.27	235.56		
	Cost per acre	.051	.32	.04		
	Cost per MBM	10.48	7.93	10.75		
	% treated	Data not available until 1925 survey.				

Chart I.

Diagram of Yellow Pine Losses from Western Pine Beetle
On Units of the San Joaquin Project.

The volumne killed annually is represented by height of perpendicular column. The volumne of timber killed by summer broods, i.e., from May 1 to August 20, is shown in the lower left section of each columne. The volumne killed by overwintering broods (from August 15 to November 1) is represented by the upper right half of the same columne. The volumne of timber that was not treated is represented by the open portion of the columne, bounded by white line.

The upper series of units are check areas which were either worked only for the first two years or were not worked at all. The lower series of units were those on which more or less control work was carried on throughout the five seasons of the project.

Diagram of Yellow Pine Losses from Western Pine Beetle on Units of San Joaquin Project

Showing Volumes Killed by Summer & Winter Broods & Volumes Treated by Control Work

Volume-Bd.Ft.

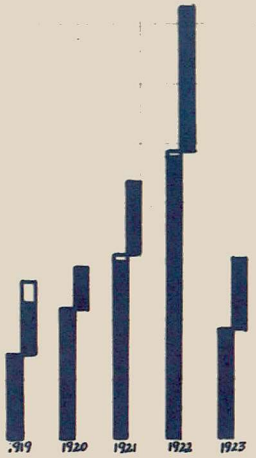
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000

24b. Rock Creek

7,680 A. Check Area—not adjacent to control work

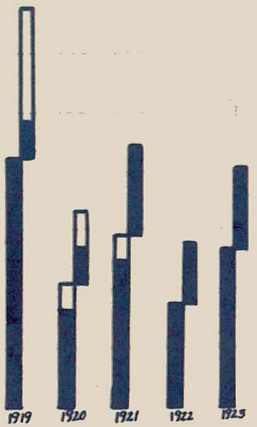
27. Jackass Creek

6,400 A. Check Area—adjacent to maintenance control work.



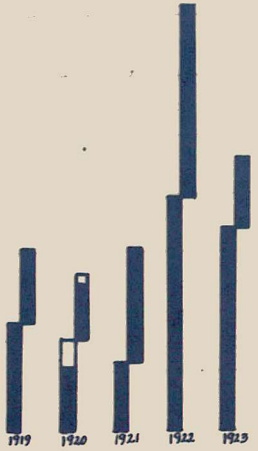
30. Crane Valley

7,600 A. Spring & summer work—two seasons only.



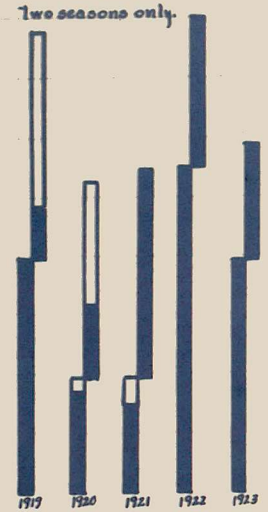
24a. North fork

16000 A. Spring & summer work—two seasons only



24. Hogue Ranch

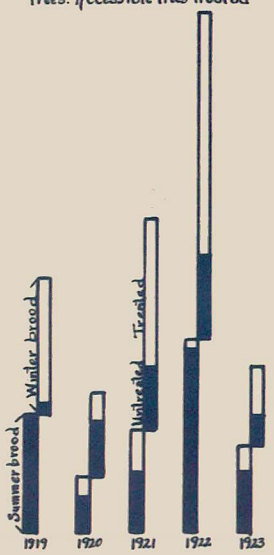
8,300 A. Spring & Summer work—two seasons only.



300,000
275,000
250,000
225,000
200,000
175,000
150,000
125,000
100,000
75,000
50,000
25,000

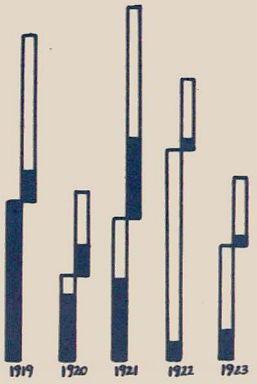
26a. Logan Meadow

5,440 A. — Maintenance Control Spring and summer work with trap trees. Accessible trees treated



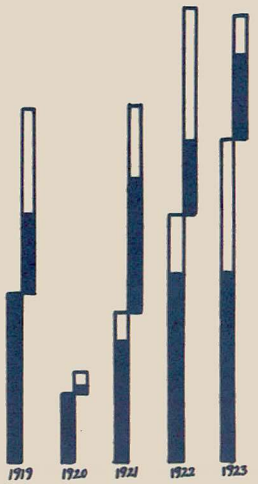
26b. Forked Meadow

3200 A. Maintenance Control Extermination—as near 100% of seasonal infestation as could be treated



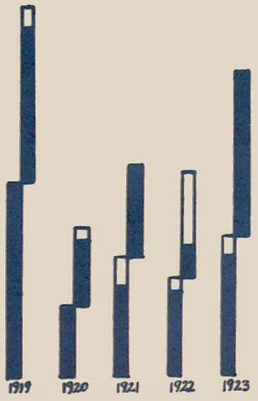
26c West Chiquito

5760 A. Maintenance Control Spring & Summer Work without Trap trees. Accessible trees treated.



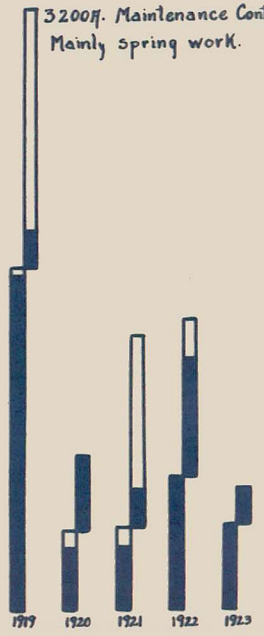
26d Arnold Meadow

5,120 A. Maintenance Control. Occasional spring & Summer work on accessible parts of unit



28. Dalton Meadow.

3200 A. Maintenance Control Mainly Spring work.

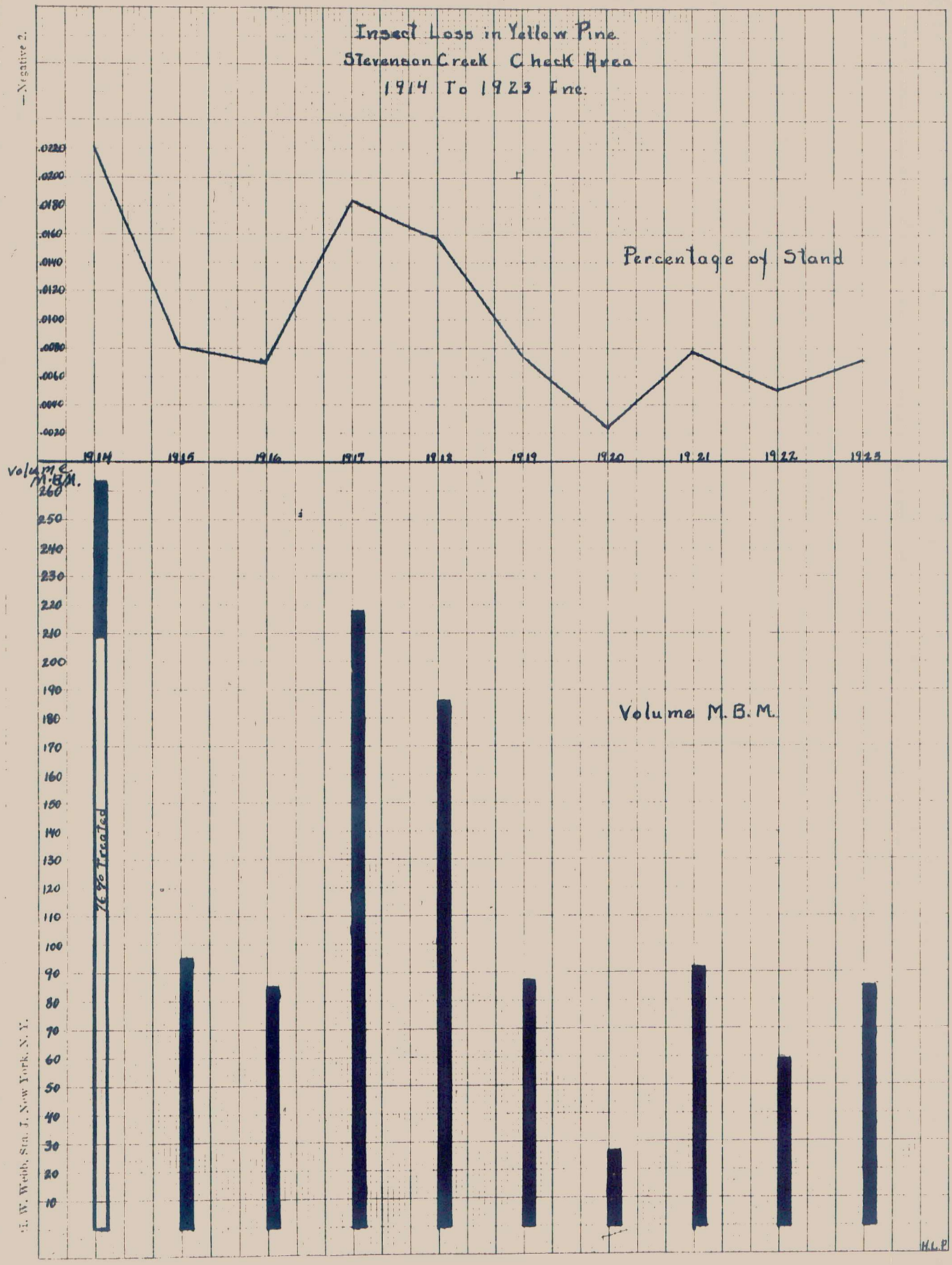


J. Miller—H. Person.

Chart II.

Diagram of Yellow Pine Losses from Western Pine Beetle on Units of the San Joaquin Area.

This area was first marked in 1914 by Mr. Ralph Hopping who continued records until 1918. The area was marked by the Bureau of Entomology from 1919 to 1923. In 1914, 76% of the infestation was treated. The volumnes killed annually from 1914 to 1923 are shown by the columns on lower half of page. Percentage of stand killed annually is shown on upper part of page.



—Negative 2.

E. W. Webb, Sta. I, New York, N. Y.